The Impact of the Use of New Technologies on Farmers' Wheat Yield in Ethiopia: Evidence from a Randomized Control Trial

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Abstract

This study examines the impact of the Wheat Initiative technology package promoted by the research and extension systems in Ethiopia on wheat growers in the highlands of the country. The package includes improved wheat seed, a lower seeding density, row planting, fertilizer recommendations, and marketing assistance. A sample of 490 wheat growers was randomly assigned to one of three groups: the full-package intervention group, a marketing-assistance-only group, and a control group. The results suggest that the full-package farmers had around 14 percent higher yields after controlling for the type of farmer and household characteristics. Implementation of the Wheat Initiative was successful in terms of the distribution of improved seed and fertilizer, though only 61 percent of the intervention group adopted row planting and few farmers received marketing assistance. The measured yield difference may underestimate the true yield difference associated with the technology because of incomplete adoption of the recommended practices by intervention farmers and adoption of some practices by control farmers.

Keywords: Agricultural practices, yield, randomized controlled trial, Ethiopia.

1. Introduction

Agricultural production in developing countries often falls short of its potential. In sub-Saharan Africa, the majority of agricultural producers are relatively poor, smallholder farmers with limited use of basic technologies such as adequate seeds and fertilizers (Gollin, Parente and Rogerson 2002 World Bank 2007, Minot and Benson 2009, Byerlee et al. 2007, Rashid et al. 2013, Sheahan and Barrett 2014). A longstanding literature on adoption of agricultural technologies identifies a number of factors contributing to low adoption rates including input, output, land, labor, credit and insurance markets inefficiencies in addition to issues of lack of information and sub-optimal behavior (see Jack 2011 for an extensive review). Yet if one binding constraint is overcome, another constraint could immediately hinder adoption. Recent empirical studies have started to investigate which constraints dominate, and whether overcoming more than one constraint has complimentary benefits. In Ghana, for instance, Karlan et al. (2014) find that the combined provision of insurance and grants does not lead to more adoption than the provision of insurance only.

Agricultural technologies themselves often complement one another. Some improved seeds may only increase yields if adequate fertilizer and proper seeding rates are applied (Dercon et al. 2009; Byerlee et al. 2007; Howard et al. 2003). Lifting constraints to the adoption of improved seeds may lead to low economic returns and thus low adoption rates unless fertilizers are readily accessible and extension services functional. Thus, public agricultural investments in Sub-Saharan Africa have recently shown renewed interest in "package" approaches. These approaches seek to increase farm productivity by addressing issues of market inefficiencies and limited information simultaneously for a group of complementary inputs. The package approach assumes that the provision of complementary inputs and extension will ensure that the input mix and its application by farmers approaches that of controlled agronomic trials, leading to optimal yield outcomes. Yet, large-scale implementation of package approaches may suffer from logistical difficulties that are less binding in agronomic trials. Large quantities of inputs and extension services must be of homogeneous quality and delivered on time to numerous farmers in remote locations. Further, even in such programs, smallholder farmers make decisions about what parts of the package to actually implement, and they may not exactly follow recommendations about input use.

In this paper, we present the results of a one-year randomized evaluation of the impact of a package approach promoted in Ethiopia on smallholders' effective adoption of technologies and yields. Together with the Ministry of Agriculture, Ethiopia's Agricultural Transformation Agency (ATA) has developed packages of inputs, extension services and marketing plans for specific crops or food products. The wheat package includes the use of improved wheat seed, lower seeding rates, row planting, and balanced use of urea and diammonium phosphate (DAP). To promote the package, a small group of selected farmers in each village were provided with training in agronomic practices (e.g. row planting, reduced seeding rate), improved wheat seed on credit, urea for free, and some marketing assistance. To evaluate the introduction of the wheat package, we worked with the ATA to expand the list of potential farmers to receive the initial intervention. Within *kebeles*, farmers were then randomized into three groups: a complete package group; a group selected only for the marketing arm of the intervention; and a control group.[2] Due to the individual level randomization, we can present impact estimates that control for unobservable factors at the *kebele* level.

At harvest, we find that the complete wheat package increased yields by approximately 14 percent. While significant, this yield increase is well below the program's initial expectations based on agronomic trials. We also find that, absent input support, the marketing assistance intervention did not affect yields. For most of its components, we find that the program was well executed: inputs were delivered on time; beneficiaries were satisfied with the quality of inputs received; and extension services reached all targeted farmers and effectively raised knowledge. The marketing support component is the only one with implementation issues, with only 16 percent of the targeted farmers reporting benefiting from it. Regarding farmers' effective implementation of the recommended technologies, our results point to higher yet partial implementation of the package. Seeding rate among beneficiaries is lower than among control households, but remains 53 percent higher than the recommended rate. Fertilizer application is 26 percent below the recommended amount. Only 61 percent of the farmers relied on row planting, due to either labor constraints or feeling that their soil type was inappropriate for such technology. Lastly, we assess whether these impact estimates are artificially lowered due to positive spillovers from treatment farmers to control farmers, in the same *kebele*.[3] Using physical distance from treated farmers, we find evidence of positive spillover on knowledge sharing, but no detectable effect on control farmers' behavior or yields.

Overall, our results point to the effectiveness of package interventions to support smallholders' adoption of agricultural technology. These are in line with Abay et al. (2016) who study farmers' adoption decisions in Ethiopia and find 70 percent complementarity between the use of chemical fertilizers and improved seeds, and up to 23 percent between these two inputs and extension services. In neighboring Kenya, Nyangena and Juna (2014) find that chemical fertilizers and improved seeds lead to significant increases in yields while no effect is found when either technology is used separately. Yet our results also point to lower than expected impacts, as compared to agronomic trials. Partial implementation of the marketing support part of the package may limit farmers' expected returns from adoption. For example, Bernard et al. (2016) find that changes in the functioning of output markets for onions in Senegal led to

[2] A *kebele* is the smallest administrative unit in Ethiopia.
[3] Due to the program's implementation scheme, the study did not include *kebeles* without any intervention as pure controls.

significant changes in farmers' choice of fertilizer types. Behavioral and progressive learning issues may also contribute to incomplete adoption, despite availability of inputs and extension services. It is interesting, for instance, that beneficiary farmers were unwilling to decrease seeding rate – and thus incurred higher costs – despite their acquired knowledge that it could contribute to increase yields.

A second contribution of this study is that we use three different measures of yields: a crop cut, in which a small area of the field was harvested and the output weighed; a measure that uses a farmer report of wheat production, but the actual area of the field (measured following polygon method); and a measure that uses farmer reports of wheat production and sown area. Not surprisingly, results differ somewhat by method, which has implications for measurement of impact estimates. Using the polygon-based measurement of area as non-biased benchmark, we do not uncover systematic biases in farmers' assessment of plot size. We also find consistent estimates between crop-cut measures and farmers' pre-harvest expectation of yields. However, post-harvest recall data show a lower impact of the intervention that is not statistically significant, suggesting potential non-classical measurement errors in such measures.

The next section provides a brief background on the importance of wheat in the agricultural economy and the diet of Ethiopia and describes the Wheat Initiative as implemented by the MOA with support from the ATA. Section 3 describes the study design—sample and allocation of treatments, data, and yield measurement, which is the main variable of interest. The experimental integrity and estimation strategy is presented in Section 4. Section 5 gives the results of the study, including econometric estimates of the impact of the technology on yield, as well as descriptive analysis on potential impact pathways. Finally, Section 6 provides a summary of the main results and its implications.

2. Context

a. Wheat yields in Ethiopia

Wheat is one of Ethiopia's main staple crops in terms of both production and consumption. For caloric intake, wheat is the second-most important food in the country behind maize (FAO 2014a). Wheat is mainly grown in the highlands of Ethiopia, and the two main wheat-producing regions (Oromia and Amhara) account for about 85 percent of the national wheat production (CSA, 2013). Wheat is typically grown by smallholder farmers in Ethiopia. In the 2012/2013 *meher*[4] season, about 4.8 million farmers grew wheat, and more than 1.6 million hectares (ha) of land were dedicated to wheat cultivation, constituting 13.5 percent of the national grain area (CSA 2013). Wheat production during the 2012/2013 *meher* season

[4] Meher is the long (main) rainy and production season in Ethiopia.

was 3.4 million metric tons (mt), and has been growing over time due to both area expansion and yield improvements.

While wheat is an important cereal in Ethiopia's production systems, wheat yields are relatively low. Recent estimates show that wheat farmers in Ethiopia produce, on average, 2.1 t/ha,[5] well below the experimental yield of above 5 t/ha (Hailu 1991; MOA 2010, 2011, 2012). Ethiopia also consistently lags behind average yields in Africa and beyond. In 2012, for instance, Ethiopia's wheat yield was 29 percent below the Kenyan average, 13 percent below the African average, and 32 percent below the world average (FAO 2014b).

Several socioeconomic, abiotic, and biotic constraints combine to explain these yield gaps. The use of modern production-enhancing inputs, such as improved seeds and fertilizers, among wheat farmers in Ethiopia is remarkably low. The 2012 national estimates on input use indicate that only 8.4 percent of wheat areas were planted with improved seed and that 48 percent were fertilized. Fertilizer application rates on fertilized lands are estimated at 48 kg/ha, which is well below average recommended rates of 200 kg/ha (Spielman, Kelemwork, and Alemu 2013; Endale 2010; MOA 2010, 2011, 2012). Only about 1 percent of the wheat area was cultivated using improved seed-fertilizer package (CSA 2012), which is unfortunate given the high production response for combined use of improved seeds and fertilizers in Ethiopia (Dercon et al. 2009; Byerlee et al. 2007; Howard et al. 2003). Studies also indicate disadoption of improved seed-fertilizer over time, due to high costs, insufficient credit, and lack of improved varieties with traits appropriate to farmers' needs (EEA/EEPRI 2006).

Abiotic factors, such as low and poor distribution of rainfall in lowland areas, plant lodging in half of the highlands, soil erosion, disease, and weeds also contribute to significant wheat yield losses in the country.[6] For instance, an estimate suggests that plant lodging can cause 10 to30 percent of yield losses (Lemma et al. 1990) and yield gains with proper weed control (including through row planting and reduced seed rate) have ranged from 35 to 85 percent (Tessema, Tanner, and Hassen 1996; Tessema and Tanner 1997; Desta 2000; Bogale, Nefo, and Seboka 2011).

Furthermore, postharvest losses may undermine wheat yields in Ethiopia (Dereje 2000). According to the African Post Harvest Loss Information System, wheat grain yield losses in Ethiopia during harvesting, drying, handling operations, farm storage, transportation, and market storage in 2012 were

[5] There is considerable variation in average wheat yields across regions and zones. For instance, the average wheat yields in some zones of Oromia region (Arsi and Bale) and Southern Nations, Nationalities, and Peoples (SNNP) region (Hadiya and Silitie), where farm sizes are relatively large, were between 2.5 and 2.8 t/ha, which is well above the national average wheat yield (CSA 2013). On the other side, average yields are reportedly lower than the national average in most parts of Amhara and Tigray regions, ranging between 1.7 and 1.9 t/ha (CSA 2013).
[6] Plant lodging occurs when either the stalk bends or roots are not well anchored and the entire plant falls over.

estimated at 14.2 percent. Finally, the way farmers' plant wheat seed also contributes to low wheat productivity. Traditionally, Ethiopian farmers plant wheat seeds using hand broadcasting. Compared with direct seeding, broadcasting reduces yields due to poorer seed-to-soil contact and delayed germination, higher competition between plants for inputs because of uneven seed distribution, and difficulty in controlling grassy weeds.

The results of on-station and on-farm trials following the System of Wheat Intensification led to optimism about the potential of the comprehensive extension package to address the aforementioned constraints and increase wheat productivity (Abraham et al. 2014).[7] For instance, on-farm trials in northern Ethiopia and South Wollo showed that optimal use of inputs, row planting with reduced seeding rate, and proper implementation of agronomic best practices increased wheat yield by a factor of 2.7 on average, compared with control plots (4.9 t/ha on experimental plots versus 1.8 t/ha on control plots). However, systematic evaluation on the yield potential of a package approach that promotes optimal use of inputs, as well as row planting and lower seeding rate on farmers' fields, is scarce.

Extant research in Ethiopia focuses primarily on measuring the impact of a single technology. A package intervention is also being promoted by the ATA to increase teff yields, which is backed by studies that found a 27 to 35 percent increase in yield for teff planted following row spacing using reduced seeding rates (Abayu, 2012; Tolosa, 2012). The intervention also includes recommending proper use of inputs. Despite such large increases predicted just for changed practices, a randomized controlled trial conducted by Vandercasteelen et al. (2013) on the actual intervention found only a 2 percent yield gain from row planting based on crop-cut data, and a 12 to 13 percent yield gain based on data from farmers' production and area estimates.

b. The ATA Wheat initiative

In the 2013 *meher* rainy season, the Ministry of Agriculture, with the support of the Ethiopian ATA, launched a Wheat Initiative that aims to address the aforementioned constraints on wheat productivity. The initiative covered about 400,000 wheat farmers in 41 *woredas* (districts) and promotes the optimal use of improved technologies and proper implementation of agronomic best practices. A main goal of the initiative is to reduce Ethiopia's reliance on imported wheat by increasing yields and productivity.

[7] The System of Wheat Intensification is a methodology for cultivation of wheat that integrates agronomic principles (principles of root development and intensive care) with package of practices in wheat crop production. The methodology specifically promotes the use of improved and treated seed, better land preparation with increased use of organic matters, lower seeding rate, line sowing, gap filling, (irrigation), and weeding/hoeing using a mechanical weeder for better soil aeration as a package (Suryawanshi, Patel, and Deore, 2012). The System of Wheat Intensification is closely related to the System of Rice Intensification, which has been critiqued as controversial (Glover 2012).

To meet this goal, the Wheat Initiative includes a comprehensive input and extension package designed to help farmers attain higher yields. As a comprehensive package approach, the initiative includes four major components: inputs, teaching optimal agronomic practices, access to finance, and market linkages.

The critical ingredient of the input component was to ensure availability, access, and adoption of improved seeds and fertilizers. The input component specifically aimed to increase the adoption rates of certified improved wheat seeds to 30 percent (from less than 10 percent) and tailored recommendation of fertilizers that require increased use of urea relative to DAP. Traditionally, most wheat farmers either used urea and DAP in equal proportion or used less urea, as the benefit of using urea is largely underestimated by wheat farmers in parts of Bale and Arsi, two of Ethiopia's largest wheat-producing regions (MOA 2012; CSA 2013).[8]

The agronomic component of the initiative aimed to increase farmers' awareness of optimal agronomic practices in wheat production. It introduced row planting, lower seeding rates, and timely weeding and hoeing. In addition to the comprehensive agronomic training provided for subject-matter specialists, extension agents, and selected benchmark farmers on wheat agronomy, the initiative made an effort to reach a larger number of wheat farmers through radio, manuals, and leaflets. For instance, in partnership with Farm Radio International, a six-week participatory radio program was conducted on wheat production in the Wheat Initiative regions. In addition, wheat agronomy manuals and leaflets were developed and distributed to extension agents and wheat producers.

The Wheat Initiative also attempts to ensure access to input finance. A new input credit delivery system was designed and implemented in some of the Wheat Initiative *woredas* that introduces input vouchers, which can be redeemed at agricultural cooperatives. The goal of the voucher system is to increase fertilizer use and repayment rates.

Finally, creating market linkages for wheat was considered an important element for the success of the Wheat Initiative. Through collaboration with the Ethiopian Grain Trade Enterprise (EGTE), the initiative made efforts to make wheat farmers aware of newly developed market opportunities. This was done by broadcasting the EGTE's domestic purchasing plan for the 2013/2014 marketing season.[9] Domestic purchases of wheat by the EGTE is believed to send out a clear demand signal to producers and

[8] The Bale and Arsi wheat belts account for 22 percent of the total wheat area and 25 percent of total wheat production (CSA 2013).

[9] During the 2013/2014 marketing season, EGTE planned to purchase 250,000 mt of wheat from the domestic market, which is about 40 percent of EGTE's total previous year import. This plan was broadcasted on national television and radio during the planting period to encourage farmers that investment in wheat can have better access to market and yield better returns.

encourage farmers to invest in inputs and technologies, thus stimulating an increasing supply of domestic wheat.

In addition to the overall Wheat Initiative that addressed all wheat farmers in the intervention *woredas*, the MOA, with the support of ATA, rolled out a promotional package for 2,000 "benchmark" farmers in 41 *woredas* in the four major-wheat producing regions (Figure 1). The benchmark farmers were selected from 200 *kebeles* (counties) within the 41 *woredas* and, on average, constituted two model farmers, two non-model farmers, and one female farmer. The promotional wheat package was implemented on benchmark farmers' plots of 0.5 ha. The package includes input and training support from the Ministry of Agriculture local extension agents regarding row planting and lower seeding rate. The input support included 50 kg of certified improved seed on credit (free of interest), 50 kg of urea fertilizer for free, and 25 kg of gypsum for free. Farmers were also made aware of the guaranteed market opportunity offered by EGTE. Our study focuses on measuring the impact of the promotional package on wheat yields of benchmark farmers.

3. Study design

a. Sample and allocation of treatment

Our study uses on 36 experimental *kebeles* spanning 18 *woredas* in the Oromia, Amhara, and Tigray regions (the 18 experimental *woredas* are shown in Figure 1). The evaluation design compares three groups of farmers. In the Benchmark or full package group, farmers benefitted from the full promotional ATA wheat package (inputs, extension and awareness of the EGTE market opportunities). In the Market group, farmers did not benefit from extension and input support, but were made aware of the of the guaranteed market opportunity offered by EGTE. Farmers in the Control group did not receive extension or input support, nor were they made aware of the EGTE market opportunity. It is assumed that market and control farmers plant wheat following the existing or traditional production practices, although they were not precluded from adopting parts of the package at their own costs.

The sample design followed a three-stage approach. In the first stage, 18 *woredas* that were able to send a list of 14 farmers by *kebele* were selected for the evaluation; each of these *woredas* constitutes between 4 and 10 *kebeles*. In the second stage, 2 *kebeles* per *woreda* were randomly selected. In the third stage, the 14 farmers were randomized into benchmark farmers, market farmers, and control farmers (504 wheat farmers in total), stratified by model, non-model, and female farmers in order to ensure that the mix of farmers targeted by the program was preserved within each *kebele*. Extension agents, with the support of the ATA wheat value-chain team, provided the training and assisting of farmers in implementing the promotional package.

b. Data

The paper uses two primary sources of data. First, it uses a crop-cut measurement survey, which was conducted in November and December 2013 in the 36 *kebeles* covered by the study. This survey was aimed at measuring wheat outputs and plot areas for all three groups of farmers, before harvesting. Each plot was subject to two types of output measurements: sample crop-cut output measurement (wet weight) and farmers' pre-harvest estimates of wheat outputs from the whole plot. Experts from the central statistical agency (CSA) carried out the crop-cut exercise. Of the 504 experimental and control farmers in the low-intensity *kebeles*, wheat production was successfully measured on 382 plots.[10] Second, a wheat growers' survey was conducted in February and March 2014, after harvest was complete. The survey covered 490 farmers from all three groups, and gathered information related to input use, labor use, land use, wheat production and marketing. It also asked questions about farmers' social networks and plans of growing wheat using the promotional wheat package for the next growing season.

c. Yield measurement

Our primary outcome of interest is wheat yield, defined as the amount of harvested wheat output divided by plot area, a preferred denominator to harvested area since the latter overlooks the possibility that smallholders might experience a loss in crop area between planting and harvesting, which can result in overestimates of average crop yields (Reynolds et al. 2015). The estimation of the average wheat yield on a specific plot however involves both the estimation of plot area and the quantity of output obtained from the area. Both can be challenging and prone to errors in the Ethiopian context. For example, local units used for measuring quantities and areas are inconsistent from one location to another. Thus, the evaluation used alternative estimates of crop area and harvested product to ensure the robustness of yield estimates.

The reference plots were selected based on wheat production potential in both treatment and control groups. By design, all experimental plots should have had a consistent area of 0.5 ha. However, during follow-up field visits, significant deviations from the standardized area were found. Thus, during crop-cut and wheat growers' surveys, both the experimental and control plots were subject to area measurement. The area of experimental and control plots in low-intensity *kebeles* were measured using the polygon method (direct area measurement) and farmer assessment of plot area. The polygon method involves the use of a rope and a compass to measure the length of each side and the angle of each corner; this information was then used to calculate the plot size. Farmer assessment of plot area was based on farmers' estimates of

[10] Outputs could not be measured for the remaining 122 plots for three reasons: seven of the farmers had no wheat plot during the 2013 meher season, five farmers could not be identified by anyone in their respective kebeles at the time of the household survey, and the remaining 110 farmers harvested their wheat plots early before the crop-cut survey. There were no refusals.

the surface area of their plot, all done in the presence of enumerators. The enumerators were present to judge the soundness of each farmer's estimate. Local units were used for farmer assessments of plot area to reduce potential rounding errors while converting to standard units. As reported in Figure 2, we find 76 percent correlation between polygon measurements of plot area and farmers' own estimates. The horizontal lines reflect the fact that farmers often round off their plot size estimation (for example, ½ *timad*, 1 *timad*, and 2 *timad*, which are 0.125 ha, 0.25 ha, and 0.5 ha, respectively). On the other hand, the polygon estimates of plot size had a larger share of outliers, perhaps reflecting errors in measuring or recording the angles and distances used to calculate plot size.

We use three different measures of wheat outputs. First, a crop-cut survey was conducted at the time of maximum crop maturity, just before harvest, on a random subplot of 4 m^2 or a 2 x 2 m area of the planted wheat plots. The output from this random subplot was harvested and threshed, and enumerators measured the wet weight. Second, at the time of the crop-cut exercise, farmers were asked to predict the output they expected from the whole plot. The prediction was obtained in a setting in which the enumerators and the farmers were in visual contact with the growing wheat crop so that the enumerators could judge the validity of the farmers' estimates. Lastly, postharvest estimation of output was obtained from farmers at the time of the wheat growers' survey, which was conducted right after the harvesting, drying, and threshing activities were completed.

Each yield measure has its own strengths and weaknesses. Yields from crop-cut measurement are often considered the most reliable and objective measure. However, crop-cut yield estimates do not take into account postharvest losses during drying, threshing, cleaning, and transportation. Moreover, the process of locating a subplot for crop-cut can be subject to selection bias (such as excluding the border of the plot). Finally, the 20 percent of farmers for whom crop-cut data could not be collected may systematically differ from other farmers. Although it does not reveal gross yield, farmer recall reflects the economic yield that is of use to the farmer. The benefit of yield estimates based on farmers' pre-harvest predictions is that it better reflects the attainable yield (Fermont and Benson 2011; Reynolds et al. 2015). Overall, yield measurement based on farmer prediction and recall allows the collection of a larger set of yield estimates than crop-cuts alone.

4. Empirical strategy

a. Experimental integrity

Farmers were randomly allocated into the three treatment groups (full package, marketing only, and control) in order to create three otherwise similar groups. Table 1 compares the some primary household characteristics that should be relatively time invariant, by treatment group. A Wald test of the equality of means across all three groups was used, with the results shown in the last column.

We find significant differences in gender of household head as well as household size. Female farmers make up a larger share of the full-package group (19 percent) than either of the other two groups (11 and 9 percent in marketing-only and control groups, respectively). This difference was expected, since the full package group was required to have at least one female farmer through the stratification. Farmers in the control group also tended to have somewhat larger households (7.2 members) as compared with the other two groups (6.7 and 6.4 members in full-package and marketing-only groups, respectively).

We also uncover evidence of potential differences in the age of the farmer, ownership of cellphone, and the share of red and black soil. Control farmers tended to be somewhat older than those in the other groups, with the difference being two to three years, on average. Control farmers were also more likely to have red soils and less likely to have black soils as compared with the other two groups. On the other hand, the vast majority of farmers in the full package group tended to have cellphones (83 percent) as compared to the farmers in market only (73 percent) and control groups (72 percent). There were no statistically significant differences in education, housing, ownership of assets (e.g. land, livestock, radio, television, and car) and agricultural tools (e.g. plough, yoke, sickle, hay fork, winnower, and cart), the share of gray/sandy soils, and distance to plot.

We account of these slight imbalances across our treatment groups, by controlling for a set of household-level and plot-level variables, as described in our estimation strategy below.

b. Estimation strategy

We estimate the effect of the full wheat package and the market-only aspect of the package based on Equation 1 below:

$$ln\, Y_{ik} = \alpha_k + \beta T_{ik} + \gamma G_{ik} + u_{ik}, \tag{1}$$

where *Y* represents yields; *T* represents the primary treatment group, or the full package; *G* represents the marketing-only group;; and u is a mean-zero error term. *i* indexes households; and *k* indexes *kebeles*, so referencing α by *k* implies the use of *kebele* level fixed effects. The primary null hypotheses to be tested are whether β (the difference in yields between full-package farmers and control farmers) is zero and whether γ (the difference in yields between marketing-only farmers and control farmers) is zero.

Given that the package was implemented among a variety of different farmer types, the model can be expanded to determine whether model farmers or female farmers have different wheat yields:

$$ln\, Y_{ik} = \alpha_k + \beta T_{ik} + \gamma G_{ik} + \delta_1 M_{ik} + \delta_2 F_{ik} + u_{ik}, \quad (2)$$

where M represents model farmers and F represents female farmers. The model can be expanded further to include interaction terms that examine heterogeneous treatment effects—that is, whether the benefits of treatment are different for model farmers and female farmers:

$$ln\, Y_{ik} = \alpha_k + \beta T_{ik} + \theta_1 T_{ik} M_{ik} + \theta_2 T_{ik} F_{ik} + \gamma G_{ik} + \delta_1 M_{ik} + \delta_2 F_{ik} + u_{ik}. \quad (3)$$

Finally, by controlling for some household and plot characteristics (Z) that are unlikely to change over time, the specification becomes:

$$ln\, Y_{ik} = \alpha_k + \beta T_{ik} + \theta_1 T_{ik} M_{ik} + \theta_2 T_{ik} F_{ik} + \gamma G_{ik} + \delta_1 M_{ik} + \delta_2 F_{ik} + Z'_{ik}\omega + u_{ik}. \quad (4)$$

where Z is a vector of household and plot characteristics including the age of the household head, its education level, the landholding size, the household size, the soil quality, and the distance to plot from home.

5. Results and Discussion

a. Descriptive evidence

Table 2 present naive differences in wheat yield across groups. Dividing outputs from crop-cut, farmer prediction, and farmer recall after harvest by the area of the plot gives three different measures of yield: yield from crop-cut, yield from farmer prediction, and yield from farmer recall. Regardless of how the yields are measured, they are higher among farmers receiving the full package than among those who did not. According to the crop-cut, yields averaged 2.92 t/ha among the full-package farmers, compared with 2.77 and 2.73 t/ha among the market and control farmers, respectively (all of which also rely on crop-cut based estimates). Interestingly, estimates from all three groups display higher average yields than that of Ethiopia as a whole (2.1 t/ha), or that of control plots of agronomic trials (1.8 t/ha), reflecting the fact that farmers in targeted *kebeles* are amongst the more productive ones. Yet, average yields obtained in the group of full-package farmers stand well below the average for treatment plots in agronomic trials (4.9 t/ha), despite their access to all necessary inputs and know-how.

Yield estimates from farmers' predicted output pre-harvest and farmers' recalled output post-harvest are higher on average compared to the crop-cut. A simple means difference tests of predicted and recall yields between farmers with and without crop-cut data indicates that relatively low yield figures from the crop-cut are partly due to the missing farmer who did not participate in the crop-cut, because they has harvested their wheat before the crop-cut team arrived. We examine yields using the second and third yield definitions and find that the farmers not available from crop-cuts systematically reported higher yields than other farmers. Additional explanations could be that farmers over reported their production to enumerators, or perhaps crop-cuts were done on less-productive parts of fields. Later in the paper is a detailed examination of this difference in the data.

b. Impact estimates

In the following tables, we report the Intent-to-Treat (ITT) estimates of the wheat package on farmers' yields, and test for their sensitivity to the yields measurement tools. Table 3 reports estimates based on the crop-cut based yield measurement. With only the two treatment variables in the regression, we find a positive coefficient on the full package indicator (0.078), but it is not significantly different from zero (column 1). Next, we control for the type of farmer (model farmers and female farmers), and the coefficient estimate increases to 0.094, but remains statistically insignificant (column 2). Interaction terms between the treatment and the model/female farmer indicators are next included, and although neither coefficient estimate on an interaction term is statistically different from zero, adding these variables increases the main treatment effect to 0.124, which is then significant at the 10 percent level (column 3). Fourth, household and plot level control variables are added (column 4), and the coefficient estimate increases further to 0.134, remaining significant at the 10 percent level. This coefficient estimate implies a yield increase of approximately 14 percent. Whereas these results may not appear to be strong evidence of an impact of the Wheat Initiative, note that the sample size was reduced as some farmers had already harvested at the time of the crop-cut, and so statistical power is not as high as in the full sample. We find evidence of lower yields for female farmers in one specification (column 3), and wheat yields on "black cotton" soils (vertisols) are about 22 percent below yields from other soils. Farm size, education of the head of household, and other household characteristics were not statistically significant predictors of wheat yields.

Table 4 broadly confirms these results, using farmers' pre-harvest prediction of output and farmers' assessment of plot size to compute yields. In this table, average impacts among the full package group are always significant at the 10 percent level, and coefficient estimates in columns 3 and 4 (0.135) are significant at the five percent level. The coefficient estimate implies that the full package led to an increase in wheat yields of 14.4 percent. The results thus indicate a strong yield impact of the promotional wheat package on benchmark farmers. Like the yield impact estimates based on crop-cut, the yield impact estimates based on farmer yield prediction indicate no significant yield impact among those farmers who were supposed to receive marketing assistance alone. The results in Table 4 also suggest a heterogeneous treatment effect. The coefficient on the interaction between the full-package and female farmers is negative, suggesting that the female farmers may gain less than male farmers from the full package. When we conduct a joint test of the main coefficient and its interaction term, it is marginally significant in column 3 (a *p*-value of 0.096) but not significant in column 4 (*p*-value of 0.114).

Lastly, results from similar estimations are reported in Table 5, where yields are now computed based on farmers' recall of output after harvest completion, combined with farmer assessment of plot size. In contrast with previous estimates, we find no statistically significant relationship between the full-package indicator variable and wheat yields. Lack of accuracy on recall questions could imply higher unexplained variance and consecutively higher standard errors. However, though all coefficient estimates are positive in magnitude, point estimates are less than 50 percent of those obtained using alternative yield measures, suggesting that errors in reporting may itself be related to receiving the full-package – in this case full-package farmers would under-estimate their yields as compared to control farmers. Similarly, we note that model farmers reported higher yields by between 13 and 18 percent relative to non-model farmers. Because this result does not appear in the other two measures of yield, it may be that model farmers overestimate their yields or that other farmers underestimate their yields.

c. Channels

Given the results from the crop-cut and yields based on predicted output over actual sown area, we next explore pathways that could have led to these findings. We explore pathways towards impacts through a set of questions related to farmers' knowledge of the components of the promotional wheat package, their experience in receiving the intervention components, and whether or not they implemented the recommendations. In addition, farmers were asked about their opinion of the Wheat Initiative recommendations and their plans about implementing recommendations for the next year, both of which are indicators of the likelihood that farmers will adopt the recommendations.

Knowledge: Table 6 first investigates differences in knowledge across the study groups. Whereas almost all of the full-package benchmark farmers were aware of the Wheat Initiative, just over half of the marketing-only and control-group farmers knew of it; in other words, there is a significant correlation between full package treatment status and knowledge on the Wheat Intervention. There is no evidence that the marketing only farmers knew more of the package than the control group. There is also a large, statistically significant difference between farmers in the full package group and in the other two groups in terms of their access to wheat production method trainings (59.1 percentage points; row 2). Further, we find that the marketing group reports receiving training on wheat production methods 10 percentage points more often than the control group. Model farmers are also more likely to have participated in trainings than other farmers.

Though full package farmers are far more likely to be trained or to have heard of the Wheat Initiative, we do not find evidence that full package group knows more of the Wheat Initiative recommendations than other groups (rows 3-7). More than 90 percent of farmers in all three groups heard about the new wheat recommendations or package from other sources, and almost all respondents knew they should use improved seed. Farmers generally also knew about the recommendations to reduce the seeding rate (85–91 percent) and to use row planting (83–91 percent). There were differences in farmers' knowledge of recommended fertilizer application rates, though all three groups of farmers on average overestimated the recommended fertilizer application rates. Full-package farmers suggested lower recommended rates than other farmers, indicating that their estimates were closer to the actual recommendation rates. It is worth mentioning that the treatment improved female farmers' knowledge on use of improved seed (column 3). Overall, while we discover some difference on access to information and training, we do not uncover large differences in farmers' knowledge regarding production practices. This finding may either reflect initially high knowledge of such practices within the study area, or potentially large knowledge spillovers from full package farmers exposed to the Wheat Initiative extension services to control group farmers.

Program implementation: We next report on farmers' experiences with the services provided by the Wheat Initiative, again by treatment status (Table 7). As noted earlier, full package farmers were supposed to receive three major incentives to participate in the wheat initiative: (1) improved seeds on credit, (2) urea fertilizer for free, and (3) training on agronomic best practices, mainly on row planting and reduced seed rate. We find that most full package farmers received improved seed on time; the treatment effect is 66.3 percentage points (column 1). However, note that 29.3 percent of control group farmers reported receiving improved seed from the Initiative, suggesting there was measurable leakage from the package. That said, a larger share of farmers who received seed in the full package group reported that it was of very good quality than in the control or marketing groups; virtually all-full package farmers reported very good quality seed versus 65.3 percent of the control group. As intended by the Wheat Initiative, full package farmers received good quality seed. Similar patterns are found with regards to fertilizers: a significant percentage of full package farmers indicated that they received the free urea and gypsum on time, relative to control-group farmers (column 3 and 5). However, again we find control group farmers who received free inputs—16.7 percent of the control group reported receiving free urea, and 4.7 percent reported receiving free gypsum. Full package farmers were also much more likely to report the quality of urea received was very good; the difference between the full package group and the control group was 47.6 percentage points.

Almost all of the coefficient estimates on the marketing group have not been different from zero to this point, and column 6 suggests a strong explanation. Neither the full package nor the marketing assistance group farmers were more likely to receive marketing assistance than the control group. As 16 percent of the control group reported receiving marketing assistance, this component of the intervention clearly did not occur as planned.

Lastly, consistent to our expectation, the results in column 7 indicates that significant percentage of the full package farmers grow wheat differently during the 2013 *meher* season (the year the Wheat Initiative was implemented) than the farmers in the control-group. As it can be seen in the second row of Table 7, there is no statistically significant difference between the marketing farmers (the second treatment arm) and control farmers in terms of their access to the components of the Wheat Initiative package, which is plausible except for the marketing assistant component. Overall, implementation of the wheat package seems to have mostly functioned through higher access to inputs (seeds and fertilizer) while marketing assistance services were not fully implemented. Therefore, the non-results obtained in terms of yields impact for the marketing only group may merely reflect the weak implementation of this part of the program.

Adoption of agricultural technologies: The wheat package offered to full package farmers included training on optimal agronomic practices and availability of agricultural inputs that are less accessible and customarily less used by wheat farmers (such as improved seed, urea fertilizer, and gypsum). Full package farmers were asked to complement these inputs by investing in and properly applying the remaining components of the package, such as DAP fertilizer, pesticides, and herbicides. Table 8 investigates the extent to which full package farmers adopted the package components, in comparison to the other two groups of farmers. Results show that almost all full package farmers planted improved wheat seeds, and nearly all applied both urea and DAP fertilizers on their experimental plots. We find a 50-percentage point difference in improved seed use over the control group for seeds, and an 11.8 percentage point difference for urea. Likewise, in relative terms, the full package farmers did follow the recommendation to reduce the seeding rate; on average, they planted about 24 kilograms fewer seeds per hectare than the farmers in the marketing only and control groups (column 2). Whereas fertilizer use rates were higher in all three groups than the Ethiopia-wide averages reported in Section 2, they remain slightly lower than the recommended 200 kg/ha. Further, full package farmers were more likely to apply gypsum (column 6) and use row planting (column 10) than marketing-only farmers and the control group, albeit not most of them. The qualitative data collection suggested that some (full package) farmers did not use row planting because of the extra labor requirement, while others felt that row planting was impractical because they had “black cotton” soils (vertisols). Table 8 also shows significant differences in input use among full package farmers as compared with marketing-only and control-group farmers. Full package farmers are no more likely to use pesticides or herbicides than the other two groups. Overall, as indicated above, main effect of the Wheat Initiative seems related to enhanced access to seeds and fertilizers. There appears to also be some movement towards a lower seeding rate and row planting, though not all full package farmers followed all recommendations.

Sustained adoption: The success of the Wheat Initiative package ultimately depend on full package adoption both by farmers in the intervention as well as neighboring farmers in the future, particularly once subsidies are removed. Table 9 presents farmer plans for the following wheat growing season (*meher* 2014/2015), focusing on the practices recommended by the Wheat Initiative. Whereas 80 percent of the farmers stated their willingness to plant improved wheat seeds for the next season, even if they have to pay cash for it, there is no statistically significant difference between the full package and control farmers on their plan to use improved seeds (column 1 and 2). Field observations suggest that farmers are generally eager to use seeds with locally appropriate traits, but the availability of such seeds is the binding constraint. More significantly, full package farmers are 18.6 percentage points more likely to adopt row planting compared to farmers in marketing-only and control groups (column 3). Farmers indicated that even if planting in row increases yields, the additional labor requirement, coupled with the higher labor costs is the main reason for their preference for traditional hand broadcasting. Like that of row planting, full package farmers are more likely to follow the recommendation to reduce the seeding rate than farmers in the other two categories (column 4). Farmers deciding to maintain the traditional seeding rate indicated that they are unsure whether the reduced seeding rate increases yields. In some contexts, farmers also stated that the reduced seeding rate may lead to weed infestation and lower production of straw. With regard to fertilizer, about 50 percent plan to use at least the recommended fertilizer application rates for the coming season and the remainder indicated that they have been applying the recommended fertilizer rates and will continue to do so. Overall, these results suggest both gradual changes of practices by farmers, needing to witness more evidence of the effectiveness of promoted technologies (such as lower seeding rates and row planting). They also suggest the important need to factor in labor costs associated with technology adoption, as labor-intensive techniques may be more difficult to convince farmers to implement.

d. Potential spillover effects

We test for the presence of potential spillover effects using control farmers' proximity to full package farmers and its correlation with the likelihood of receiving advice on the Wheat Initiative, implementation of the components of the package, and yield (Table 10). For each farmer in the control group, we compute the distance to the closest full treatment farmer using GPS recording of homesteads, and estimate the median of this distance within our sample. Our estimates are based on a dummy variable equal to one if a control farmer's distance to the nearest treatment one is below the sample median, and zero otherwise.

We find evidence of spillovers through the positive effect of proximity to full package farmers on one's probability to have received advices related to wheat production methods. However, results from columns 3 through 8 indicate that proximity to the full package farmers has no detectable effect on implementation of the Wheat Initiative package components by control farmers. Likewise, being closer to full package farmers has no statistically significant effect on the yields of control farmers. Thus, the reported impact estimates likely represent a low bound on the true estimate, although we believe this evidence suggests the magnitude of any spillover effects is limited.

6. Conclusion

Package interventions are potentially attractive ways to try to overcome multiple adoption constraints at once. In this paper, we evaluate the impacts of the Ethiopian ATA Wheat Initiative on wheat yields, using three different measures of yields. Starting with a list of 14 farmers each in 36 *kebeles*, farmers were randomly allocated the farmers into two treatment groups and a control group. The two treatments were full package group was supposed to receive production and marketing assistance, a marketing group was supposed to receive only marketing assistance. We find that the full package intervention had a 14 percent increase on wheat yields, measured with both crop-cuts and farmer predicted yields, once we control for the farmer type and household characteristics. Farmer-recall data showed a smaller and statistically insignificant yield increase, which is likely, attributable to measurement error in both the numerator and denominator, and demonstrates that one should use data on farmer reports of plot size and production cautiously.

We then trace how farmers actually implemented components of the Wheat Initiative. In terms of the use of material inputs, farmers in the full package group were much more likely to use improved seeds and received quality fertilizer from the Wheat Initiative than the control group; however, in both cases we find leakage of subsidized inputs to the control group, implying that impact estimates for the package as implemented may be slight underestimates. We find that full package farmers far more likely to apply gypsum to their fields than control group or marketing group farmers, but no more likely to use pesticides or herbicides.

In terms of techniques, we find that full package farmers did reduce seeding rates and were more likely to try row planting than control group farmers, who also appear generally aware of the Wheat Initiative recommendations. Whereas most farmers in all groups were aware of new recommendations, not all full package farmers followed all recommendations about techniques, and whereas they reduced the seeding rate, we find that they did not reduce the seeding rate as much as recommended. Full package farmers were more likely to suggest they would use reduced seeding rates and increase row planting in the following season, but differences between the full package group and the control group were small. So whereas changing material input rates when they are made available is not that difficult, changing farmer behavior takes more time, and likely contributes to the difference between findings from agronomic trials that suggest substantial yield increases, and results from RCTs like this one. That said, to the extent that farmers learn how to use these practices over time, yield increases may continue into the future. Yet in particular farmers with soil types that are more difficult to row plant may not adopt that technique, due to the implicit cost of additional labor to do so. Clearly, when planning package interventions it is important to consider how labor allocations would need to change.

Lastly, the marketing component of the intervention effectively did not take place, as only 13 to 16 percent of farmers reported receiving marketing assistance. Whereas the implementation of other components of the intervention went quite well, the marketing assistance was effectively not implemented. Ensuring that farmers can link to markets to sell excess production would further reduce uncertainty among farmers about their potential profits and could also stimulate the use of improved agronomic practices; this hypothesis deserves further attention in future research.

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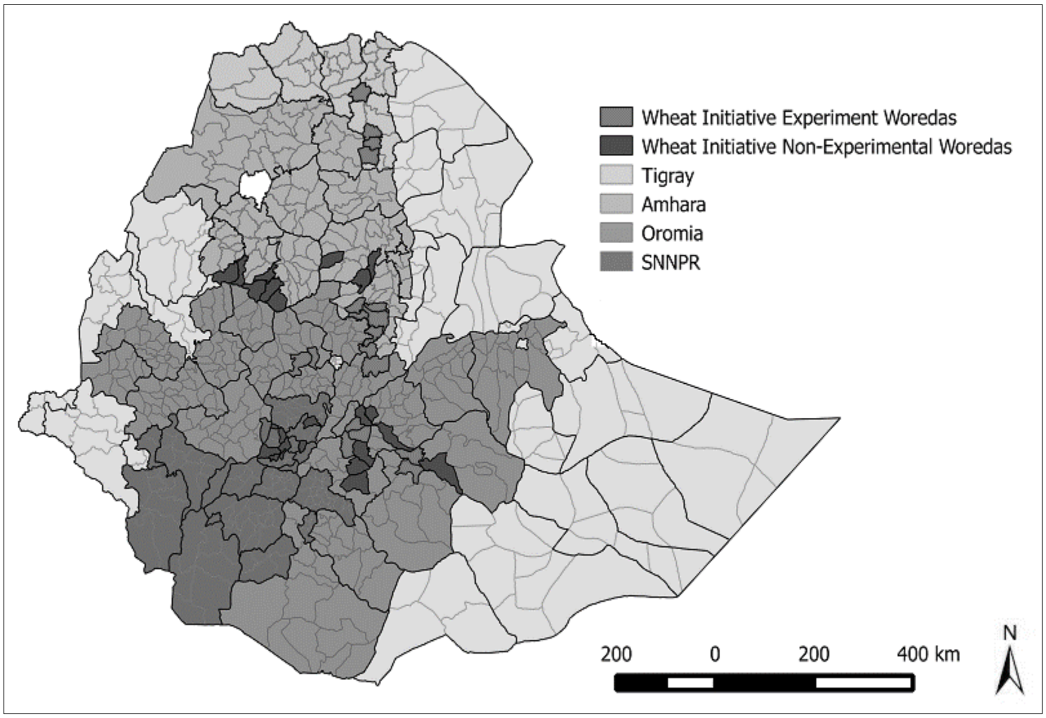
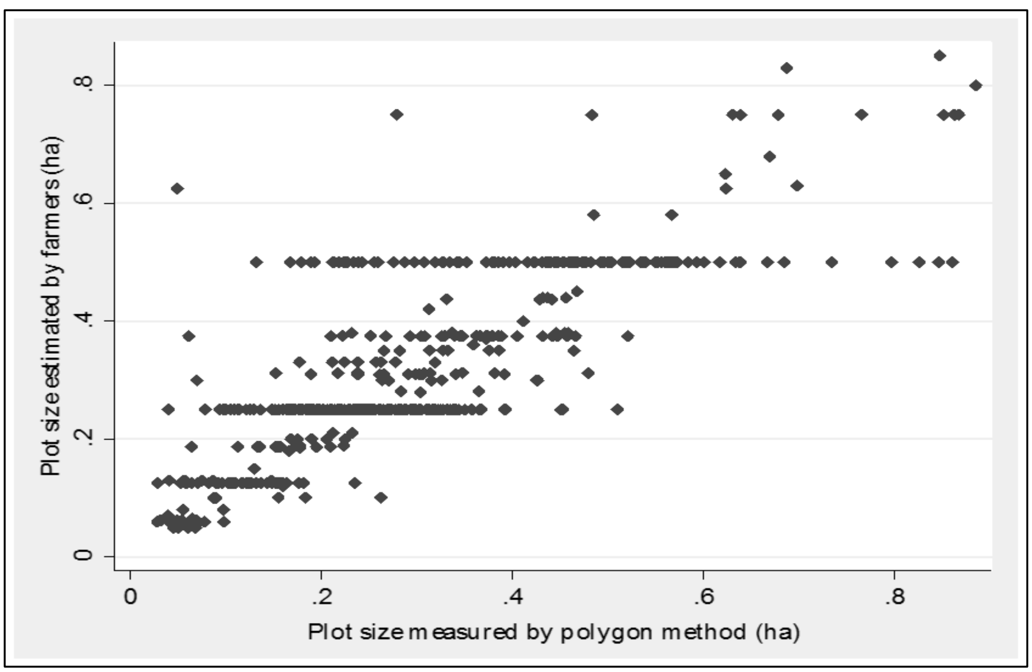
Figure 1 Map of the Wheat Initiative regions and *woredas*



Source: Authors.

Figure 2 Scatter plot between plot size measured by polygon method and farmer assessment



Source: Authors' calculation based on crop-cut survey data.

Table 1 Characteristics of households in each treatment group

Variable	Full-package farmers (n=197)	Marketing farmers (n=126)	Control farmers (n=167)	F-test of differences in means
HH head Age *(year)*	45.5	44.0	47.1	2.87*
HH head Gender *(1 = male, 0 = female)*	0.79	0.89	0.91	11.84***
HH head Education *(in completed years)*	2.62	2.63	2.56	0.23
Household size *(number)*	6.69	6.44	7.20	8.34***
Landholding size *(ha)*	2.37	2.22	2.30	0.28
Irrigated land size *(ha)*	0.015	0.018	0.039	0.99
Red-colored soil (*1 = yes)*	0.218	0.246	0.311	3.10*
Black-colored soil *(1 = yes)*	0.594	0.540	0.474	3.19*
Gray/sand-colored soil *(1 = yes)*	0.188	0.214	0.216	0.33
Distance to wheat plot *(minutes)*	13.7	15.4	14.3	0.55
Radio ownership *(1 = yes)*	0.73	0.71	0.69	0.33
Television ownership *(1 = yes)*	0.14	0.18	0.11	0.89
Cellphone ownership *(1 = yes)*	0.83	0.73	0.72	4.69**
Bicycle ownership *(1 = yes)*	0.02	0.03	0.02	0.20
Car ownership *(1 = yes)*	0.03	0.04	0.02	0.42
Livestock ownership *(number, TLU)*	11.8	10.4	10.8	2.14
Housing *(number of distinct units)*	2.68	2.71	2.69	0.04
Agricultural tools owned *(number)*				
Axe	2.37	2.25	2.41	0.81
Pick-axe	1.71	1.76	1.60	0.52
Sickle	3.99	4.06	4.04	0.05
Plough	2.17	2.09	2.08	0.28
Yoke	1.99	1.94	1.94	0.20
Hay fork	2.26	2.12	2.03	2.37
Shovel	1.19	1.25	1.14	0.72
Hoe	1.71	1.65	1.47	1.50
Winnower	1.47	1.46	1.39	0.74
Cart	0.22	0.23	0.22	0.00
Water pump	0.06	0.03	0.08	0.91

Source: Authors' calculation based on data from the crop-cutting exercise and the 2014 wheat growers' survey.
Note: Number of observation=490. Indicates statistically significant difference with the control farmers *** at the1% level, ** at the 5% level, and * at the 10% level.

Table 2 Area, production (output), and yield estimates

Variable	Full-package farmers (n=197)		Marketing farmers (n=126)		Control farmers (n=167)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Plot size *(ha)*						
Measured	0.30	0.18	0.37	0.34	0.45	0.56
Estimated by farmers	0.33	0.17	0.43	0.52	0.45	0.48
Output (production)						
Crop-cut (4 x 4 m^2) *(kg)*	4.68	2.60	4.43	2.16	4.37	2.33
Farmer prediction *(t)*	1.19	0.86	1.27	1.67	1.55	2.18
Farmer recall *(t)*	1.98	1.82	2.25	1.86	2.11	2.05
Yield estimates *(t/ha)*						
Yield based on crop-cut	2.92	1.62	2.77	1.35	2.73	1.45
Yield based on farmer prediction	3.56*	1.84	3.13	1.71	3.18	1.70
Yield based on farmer recall	3.18	1.83	3.07	1.74	2.91	1.85

Source: Authors’ calculation based on data from the crop-cutting exercise and the 2014 wheat growers’ survey.
Note: Indicates statistically significant difference with the control farmers * at the 10% level.

Table 3 The impact of the promotional wheat package on farmers' wheat yield based on crop-cut estimates

Explanatory variable	Dependent variable: yield based on crop-cut			
	(1)	(2)	(3)	(4)
Full package	0.078	0.094	0.124*	0.134*
	(0.057)	(0.059)	(0.074)	(0.074)
Marketing assistance	-0.019	-0.016	-0.014	-0.014
	(0.064)	(0.064)	(0.064)	(0.064)
Model farmer		-0.020	0.047	0.038
		(0.055)	(0.073)	(0.075)
Female farmer		–0.098	–0.190*	–0.152
		(0.072)	(0.110)	(0.113)
Treatment × model			–0.150	–0.127
			(0.110)	(0.110)
Treatment × female			0.146	0.131
			(0.147)	(0.147)
Age of household head				-0.004
				(0.002)
Education of household head				0.001
				(0.030)
Household size				0.024
				(0.016)
Landholding size				0.006
				(0.012)
Black soil				-0.203**
				(0.069)
Gray/sandy soil				-0.051
				(0.079)
Distance to plot				<0.001
				(0.002)
Kebele fixed effect	Yes	Yes	Yes	Yes
Number of obs.	367	367	367	367
R-squared	0.51	0.52	0.52	0.54

Source: Authors' calculation based on data from the crop-cut and the 2014 wheat growers' survey.

Notes: Standard errors in parentheses are calculated at the kebele level. Indicates statistically significant difference *** at the 1% level, ** at the 5% level, and * at the 10% level. In the interaction terms, *treatment* refers to the full-package treatment.

Table 4 The impact of the promotional wheat package on farmers' wheat yield based on farmer prediction of output

Explanatory variable	Dependent variable: yield based on farmer prediction			
	(1)	(2)	(3)	(4)
Full package	0.102*	0.102*	0.135**	0.135**
	(0.053)	(0.054)	(0.068)	(0.069)
Marketing assistance	0.003	0.003	–0.000	0.002
	(0.059)	(0.059)	(0.059)	(0.060)
Model farmer		0.046	0.035	0.041
		(0.051)	(0.069)	(0.071)
Female farmer		–0.047	0.121	0.158
		(0.069)	(0.105)	(0.108)
Treatment × model			0.019	0.022
			(0.104)	(0.105)
Treatment × female			–0.292**	–0.295**
			(0.140)	(0.141)
Age of household head				0.000
				(0.002)
Education of household head				0.042
				(0.028)
Household size				–0.001
				(0.016)
Landholding size				0.004
				(0.011)
Black soil				–0.085
				(0.066)
Gray/sandy soil				–0.124*
				(0.074)
Distance to plot				–0.000
				(0.001)
Kebele fixed effect	Yes	Yes	Yes	Yes
Number of obs.	482	482	482	482
R-squared	0.36	0.36	0.37	0.38

Source: Authors' calculation based on data from the 2014 wheat growers' survey.
Note: Standard errors in parentheses are calculated at the *kebele* level. Indicates statistically significant difference *** at the 1% level, ** at the 5% level, and * at the 10% level. In the interaction terms, *treatment* refers to the full-package treatment.

Table 5 The impact of the promotional wheat package on farmers' wheat yield based on farmer recall of output

Explanatory Variable	Dependent variable: yield based on farmer recall			
	(1)	(2)	(3)	(4)
Full package	0.050	0.034	0.044	0.041
	(0.057)	(0.058)	(0.073)	(0.073)
Marketing assistance	0.025	0.022	0.023	0.016
	(0.063)	(0.063)	(0.063)	(0.064)
Model farmer		0.128**	0.165**	0.184**
		(0.055)	(0.074)	(0.076)
Female farmer		–0.021	–0.091	–0.089
		(0.074)	(0.113)	(0.116)
Treatment × model			–0.078	–0.082
			(0.112)	(0.112)
Treatment × female			0.113	0.110
			(0.151)	(0.151)
Age of household head				-0.001
				(0.002)
Education of household head				0.012
				(0.030)
Household size				-0.020
				(0.017)
Landholding size				-0.006
				(0.012)
Black soil				-0.021
				(0.070)
Gray/sandy soil				0.109
				(0.079)
Distance to plot				-0.001
				(0.002)
Kebele fixed effect	Yes	Yes	Yes	Yes
Number of obs.	489	489	489	489
R-squared	0.45	0.46	0.46	0.47

Source: Authors' calculation based on data from the 2014 wheat growers' survey.

Note: Standard errors in parentheses are calculated at the kebele level. Indicates statistically significant difference *** at the 1% level, ** at the 5% level, and * at the 10% level. In the interaction terms, *treatment* refers to the full-package treatment.

Table 6 Farmers' knowledge of the promotional wheat package

Variables	Information on ATA Wheat initiative *(%, yes)*	Training on wheat production method *(%, yes)*	Package include improved seed *(%, yes)*	Package include reduced seed rate *(%, yes)*	Package include row planting *(%, yes)*	Urea application rate *(kg/ha)*	DAP application rate *(kg/ha)*
Full package	0.400***	0.591***	0.0116	0.0600	-9.47e-05	-2.128	-3.975
	(0.0570)	(0.0544)	(0.0156)	(0.0468)	(0.0407)	(7.474)	(7.862)
Marketing assistance	-0.0269	0.0974**	0.0211	-0.0239	-0.0664*	3.677	-1.943
	(0.0499)	(0.0476)	(0.0139)	(0.0410)	(0.0356)	(6.888)	(7.195)
Model farmer	0.0711	0.221***	0.0164	0.0612	0.0495	-6.461	-4.962
	(0.0594)	(0.0566)	(0.0164)	(0.0487)	(0.0423)	(7.947)	(8.286)
Female farmer	0.00495	0.0421	-0.0777***	-0.0578	-0.0628	2.237	1.820
	(0.0900)	(0.0858)	(0.0253)	(0.0738)	(0.0642)	(12.36)	(12.99)
Treatment × model	-0.125	-0.171**	-0.00476	-0.0196	-0.0397	17.93	5.383
	(0.0871)	(0.0830)	(0.0238)	(0.0714)	(0.0621)	(11.36)	(11.97)
Treatment × female	0.00239	-0.0577	0.0870***	0.0182	0.0675	1.521	4.852
	(0.117)	(0.112)	(0.0327)	(0.0963)	(0.0837)	(15.72)	(16.61)
Age of household head	-0.00185	0.00295	-0.000153	-4.19e-05	-0.000197	0.0278	-0.148
	(0.00217)	(0.00206)	(0.000605)	(0.00178)	(0.00154)	(0.298)	(0.314)
Education of household head	0.0122	0.0264	-0.00924	0.0195	0.0102	2.894	2.028
	(0.0236)	(0.0225)	(0.00658)	(0.0194)	(0.0168)	(3.193)	(3.352)
Landholding size	-0.00113	-0.0165	-0.000502	-0.00904	0.00921	-0.825	-1.006
	(0.0133)	(0.0127)	(0.00363)	(0.0109)	(0.00947)	(1.714)	(1.805)
Household size	0.00553	0.00760	-9.03e-05	0.00320	7.10e-05	0.691	2.067
	(0.00958)	(0.00914)	(0.00261)	(0.00786)	(0.00683)	(1.250)	(1.315)
Black soil	0.0268	-0.105**	0.00135	-0.0416	-0.000119	-3.480	-8.661
	(0.0546)	(0.0521)	(0.0150)	(0.0448)	(0.0389)	(7.337)	(7.743)
Gray/sandy soil	0.0179	-0.147**	0.0157	-0.0327	0.00169	-4.720	-1.238
	(0.0617)	(0.0588)	(0.0170)	(0.0506)	(0.0440)	(8.545)	(8.988)
Distance to plot	-0.00129	-0.000257	0.000390	0.000864	-0.00195*	0.326	0.144
	(0.00158)	(0.00151)	(0.000447)	(0.00129)	(0.00113)	(0.221)	(0.232)
Constant	0.576***	0.190	1.000***	0.791***	0.843***	107.2***	136.2***
	(0.147)	(0.140)	(0.0414)	(0.121)	(0.105)	(20.10)	(21.08)
Kebele fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean for control group	57.4	38.3	94.4	87.9	91.1	163.5	185.3
Observations	490	490	472	490	490	430	430
R-squared	0.244	0.404	0.106	0.181	0.408	0.539	0.575

Source: Authors' calculation based on data from the 2014 wheat growers' survey. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7 Farmers' experiences with the services provided under the Wheat Initiative

Variables	Received improved seed *(%, yes on time)*	Quality of seed *(%, very good)*	Received Urea for free *(%, yes on time)*	Quality of Urea *(%, very good)*	Received gypsum for free *(%, yes on time)*	Received marketing assistance *(%, yes)*	Grow wheat differently in 2013 meher *(%, yes)*	Know a friend/neighbor grow wheat differently in 2013 meher *(%, yes)*
Full package	0.663***	0.462***	0.742***	0.476***	0.290***	0.0410	0.338***	0.0495
	(0.0494)	(0.0581)	(0.0513)	(0.0513)	(0.0416)	(0.0458)	(0.0582)	(0.0549)
Marketing assistance	-0.0510	0.0261	-0.00241	0.0212	-0.00821	-0.00425	0.0363	-0.0906*
	(0.0432)	(0.0509)	(0.0449)	(0.0449)	(0.0364)	(0.0401)	(0.0510)	(0.0481)
Model farmer	0.0497	0.0646	0.0453	0.0409	0.0114	0.0701	0.0399	-0.0314
	(0.0514)	(0.0606)	(0.0534)	(0.0534)	(0.0433)	(0.0477)	(0.0606)	(0.0572)
Female farmer	0.138*	0.000435	0.211***	0.0271	-0.0524	-0.0543	0.0201	0.116
	(0.0779)	(0.0918)	(0.0810)	(0.0809)	(0.0656)	(0.0724)	(0.0919)	(0.0867)
Treatment × model	-0.0662	-0.0412	-0.115	0.00596	0.00636	-0.0503	0.0579	0.0437
	(0.0754)	(0.0888)	(0.0783)	(0.0783)	(0.0635)	(0.0700)	(0.0889)	(0.0839)
Treatment × female	-0.119	0.111	-0.274***	-0.0320	0.0594	0.0664	0.0479	-0.122
	(0.102)	(0.120)	(0.106)	(0.106)	(0.0856)	(0.0944)	(0.120)	(0.113)
Age of household head	0.00107	0.00398*	0.00257	0.00446**	-0.000598	3.55e-05	-0.00303	0.00223
	(0.00187)	(0.00221)	(0.00195)	(0.00195)	(0.00158)	(0.00174)	(0.00221)	(0.00208)
Education of household head	0.0206	0.00915	0.00633	0.00823	0.000708	-0.0218	-0.00281	0.0190
	(0.0205)	(0.0241)	(0.0213)	(0.0212)	(0.0172)	(0.0190)	(0.0241)	(0.0228)
Landholding size	-0.0122	-0.0170	-0.00582	-0.0221*	0.0169*	0.000495	0.0136	0.0193
	(0.0115)	(0.0135)	(0.0119)	(0.0119)	(0.00968)	(0.0107)	(0.0136)	(0.0128)
Household size	-0.00583	-0.00487	-0.00334	-0.00119	0.00197	0.000662	0.00329	-0.00433
	(0.00829)	(0.00977)	(0.00862)	(0.00861)	(0.00698)	(0.00770)	(0.00978)	(0.00923)
Black soil	0.00752	0.0210	0.0158	-0.0260	0.0339	-0.0341	0.00503	-0.0348
	(0.0473)	(0.0557)	(0.0491)	(0.0491)	(0.0398)	(0.0439)	(0.0558)	(0.0526)
Gray/sandy soil	-0.0726	-0.0402	0.0138	-0.0318	0.0650	0.0439	-0.0471	-0.0428
	(0.0534)	(0.0629)	(0.0555)	(0.0555)	(0.0450)	(0.0496)	(0.0630)	(0.0594)
Distance to plot	0.000555	-0.00169	-0.000734	0.000261	-0.00131	-0.000303	0.00114	-0.000278
	(0.00137)	(0.00161)	(0.00142)	(0.00142)	(0.00115)	(0.00127)	(0.00161)	(0.00152)
Constant	0.240*	0.0777	0.0402	-0.0929	0.00682	0.180	0.570***	0.626***
	(0.128)	(0.150)	(0.132)	(0.132)	(0.107)	(0.118)	(0.150)	(0.142)
Kebele fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean for control group	29.3	20.9	16.7	32.1	4.7	13.1	49.1	76.6
Observations	490	490	490	490	490	490	490	490
R-squared	0.534	0.334	0.493	0.363	0.400	0.186	0.284	0.213

Source: Authors' calculation based on data from the 2014 wheat growers' survey. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 8 Farmers' implementation of the promotional wheat package

Variables	Improved seed *(%, yes)*	Improved seed quantity *(kg/ha)*	Urea *(%, yes)*	Urea applied *(kg/ha)*	DAP *(%, yes)*	DAP applied *(kg/ha)*	Gypsum *(%, yes)*	Pesticide *(%, yes)*	Herbicide *(%, yes)*	Row planting *(%, yes)*
Full package	0.496***	-23.67**	0.118***	15.78	-0.00278	-2.793	0.281***	0.00901	-0.0356	0.372***
	(0.0518)	(10.45)	(0.0286)	(11.08)	(0.00882)	(10.47)	(0.0413)	(0.0410)	(0.0405)	(0.0506)
Marketing assistance	0.00798	-6.905	-0.00252	-3.849	-0.00858	-10.08	0.00350	0.0283	-0.0106	0.00147
	(0.0454)	(10.51)	(0.0250)	(9.799)	(0.00772)	(9.187)	(0.0362)	(0.0359)	(0.0355)	(0.0443)
Model farmer	0.106*	-18.82	0.0245	-2.246	-0.0149	7.918	0.0114	0.00467	0.0260	0.0669
	(0.0540)	(12.01)	(0.0298)	(11.60)	(0.00919)	(10.96)	(0.0430)	(0.0427)	(0.0422)	(0.0527)
Female farmer	0.101	-37.40**	0.0348	-4.587	-0.00160	-7.767	-0.0567	-0.0444	0.113*	0.0131
	(0.0818)	(17.76)	(0.0451)	(17.24)	(0.0139)	(16.52)	(0.0652)	(0.0647)	(0.0640)	(0.0799)
Treatment × model	-0.103	4.683	-0.0559	9.726	-0.00107	-3.101	0.0201	0.0266	-0.0168	-0.113
	(0.0791)	(15.30)	(0.0436)	(16.72)	(0.0135)	(16.04)	(0.0631)	(0.0626)	(0.0619)	(0.0773)
Treatment × female	-0.0899	24.59	-0.0379	18.53	0.00502	8.903	0.0500	0.0914	-0.0723	-0.0470
	(0.107)	(20.81)	(0.0588)	(22.27)	(0.0182)	(21.55)	(0.0850)	(0.0844)	(0.0835)	(0.104)
Age of household head	0.000205	-0.0816	0.000332	-0.228	-0.000355	-0.178	-0.000122	-0.00137	-0.00276*	-0.00254
	(0.00197)	(0.393)	(0.00108)	(0.416)	(0.000335)	(0.398)	(0.00157)	(0.00156)	(0.00154)	(0.00192)
Education of household head	0.0123	-7.414*	0.00746	-4.540	-0.000198	2.915	-0.000244	0.00173	-0.00632	0.0117
	(0.0215)	(4.398)	(0.0118)	(4.563)	(0.00366)	(4.345)	(0.0171)	(0.0170)	(0.0168)	(0.0210)
Landholding size	0.00961	-3.927	0.00805	-2.297	0.00330	-2.927	0.0142	0.0151	-0.00103	0.00858
	(0.0121)	(2.455)	(0.00665)	(2.571)	(0.00205)	(2.445)	(0.00962)	(0.00955)	(0.00944)	(0.0118)
Household size	-0.0102	-0.333	-0.00226	-2.151	-0.000141	-1.096	0.000698	-0.00286	0.00567	0.00219
	(0.00870)	(1.783)	(0.00480)	(1.875)	(0.00148)	(1.760)	(0.00694)	(0.00689)	(0.00681)	(0.00850)
Black soil	-0.0815	-0.749	0.0171	16.04	0.00531	9.209	-0.00518	-0.0257	0.0264	-0.0890*
	(0.0496)	(9.785)	(0.0274)	(10.47)	(0.00845)	(10.04)	(0.0396)	(0.0393)	(0.0388)	(0.0485)
Gray/sandy soil	-0.0920	15.68	0.0133	4.962	0.0118	17.53	0.0282	-0.0464	0.0450	0.00646
	(0.0560)	(11.45)	(0.0309)	(11.94)	(0.00955)	(11.34)	(0.0447)	(0.0444)	(0.0439)	(0.0548)
Distance to plot	0.000107	-0.207	-0.000224	-0.644**	3.95e-05	-0.563*	-0.00155	0.000256	-0.000530	0.000480
	(0.00143)	(0.293)	(0.000791)	(0.305)	(0.000244)	(0.290)	(0.00114)	(0.00114)	(0.00112)	(0.00140)
Constant	0.547***	219.7***	0.851***	172.0***	1.008***	168.5***	0.0327	0.167	0.681***	0.346***
	(0.134)	(27.68)	(0.0738)	(28.36)	(0.0228)	(27.05)	(0.107)	(0.106)	(0.105)	(0.131)
Kebele fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean for control group	51.5	177.9	91.0	129.6	100.0	153.0	4.7	8.9	59.8	26.9
Observations	490	346	490	464	490	488	490	490	490	490
R-squared	0.389	0.325	0.256	0.472	0.091	0.495	0.401	0.257	0.678	0.496

Source: Authors' calculation based on data from the 2014 wheat growers' survey. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9 Farmers' plans for adopting the promotional wheat package in the following season (2014 *meher* season)

	Plan to buy/apply . . .				
Variables	Seed if on cash *(%, yes)*	Seed if on credit *(%, yes)*	Row planting	Reduced seeding rate	Recommended (more) fertilizer
Full package	-0.0132	-0.0815	0.186***	0.0754**	0.0928
	(0.0495)	(0.0553)	(0.0567)	(0.0369)	(0.0633)
Marketing assistance	-0.0328	-0.0693	0.0714	0.00458	0.0232
	(0.0433)	(0.0485)	(0.0497)	(0.0323)	(0.0554)
Model farmer	-0.00258	-0.116**	-0.00290	0.0344	-0.0567
	(0.0515)	(0.0576)	(0.0591)	(0.0384)	(0.0659)
Female farmer	-0.0693	-0.00881	0.0818	-0.00740	-0.0461
	(0.0781)	(0.0874)	(0.0895)	(0.0582)	(0.0999)
Treatment × model	-0.0525	-0.0587	-0.124	-0.0732	-0.0541
	(0.0755)	(0.0845)	(0.0866)	(0.0563)	(0.0966)
Treatment × female	0.0485	0.0931	-0.131	0.00685	-0.0554
	(0.102)	(0.114)	(0.117)	(0.0760)	(0.130)
Age of household head	-0.00103	-0.00350*	-0.00266	-0.00482***	-0.00514**
	(0.00188)	(0.00210)	(0.00215)	(0.00140)	(0.00240)
Education of household head	0.0461**	0.0159	0.0140	0.0115	-0.0358
	(0.0205)	(0.0229)	(0.0235)	(0.0153)	(0.0262)
Landholding size	0.00302	-0.0230*	-0.0103	0.00662	0.00240
	(0.0115)	(0.0129)	(0.0132)	(0.00859)	(0.0147)
Household size	3.32e-05	0.0191**	0.0137	0.0158**	0.0265**
	(0.00831)	(0.00930)	(0.00953)	(0.00620)	(0.0106)
Black soil	0.00112	-0.139***	0.0393	-0.0169	0.0482
	(0.0474)	(0.0530)	(0.0543)	(0.0353)	(0.0606)
Gray/sandy soil	0.0663	-0.161***	0.0639	-0.0411	-0.0545
	(0.0535)	(0.0599)	(0.0614)	(0.0399)	(0.0685)
Distance to plot	-0.000281	0.00133	-0.000945	-0.000487	0.00256
	(0.00137)	(0.00153)	(0.00157)	(0.00102)	(0.00175)
Constant	0.777***	0.971***	0.268*	0.982***	0.559***
	(0.128)	(0.143)	(0.146)	(0.0953)	(0.163)
Kebele fixed effect	Yes	Yes	Yes	Yes	Yes
Mean for control group	85.6	82.6	28.7	89.8	45.5
Observations	490	490	490	490	490
R-squared	0.141	0.218	0.326	0.118	0.238

Source: Authors' calculation based on data from the 2014 wheat growers' survey. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10. Spillover effects

Variables	Received advise one wheat production from farmers *(1=yes)*	Number of farmers from whom received advise *(number)*	Row planting *(1=yes)*	Improved seed *(1=yes)*	Seeding rate *(kg)*	Applied urea *(1=yes)*	Urea application rate *(kg)*	Applied gypsum *(1=yes)*	Yield *(kg)*
Distance to treatment farmer	0.124*	0.381*	0.0781	0.00826	10.42	0.0229	-12.05	0.0113	0.0627
	(0.0743)	(0.218)	(0.0802)	(0.0730)	(18.36)	(0.0384)	(11.75)	(0.0361)	(0.0940)
Model farmer	0.0314	0.296	0.176*	0.138	-26.84	0.0636	-10.41	-0.0148	-0.0596
	(0.0942)	(0.276)	(0.102)	(0.0924)	(22.76)	(0.0486)	(14.24)	(0.0457)	(0.114)
Female farmer	0.0561	0.485	0.0174	-0.0826	-41.95	0.0802	-19.10	-0.0817	-0.0254
	(0.151)	(0.442)	(0.163)	(0.148)	(45.22)	(0.0780)	(22.32)	(0.0733)	(0.193)
Age of HH head	-0.00506	-0.0118	0.00452	-0.00215	0.529	-0.000982	0.0635	-0.00116	-0.00848
	(0.00435)	(0.0127)	(0.00469)	(0.00427)	(1.037)	(0.00224)	(0.668)	(0.00211)	(0.00569)
HH head Education	0.0313	0.0682	0.00438	-0.0207	-19.61	0.0173	-6.563	-0.00382	-0.0402
	(0.0520)	(0.152)	(0.0561)	(0.0511)	(13.90)	(0.0269)	(8.198)	(0.0253)	(0.0674)
Landholding size	0.00261	0.0785	0.0353	0.0472	-14.47	0.0257	-0.171	0.0166	0.0207
	(0.0304)	(0.0890)	(0.0328)	(0.0298)	(11.52)	(0.0157)	(4.887)	(0.0148)	(0.0365)
Household size	0.00808	0.0861	-0.0147	-0.0105	5.618	0.00147	-1.421	0.00518	0.0148
	(0.0189)	(0.0553)	(0.0204)	(0.0185)	(6.826)	(0.00974)	(3.067)	(0.00916)	(0.0244)
Black soil	-0.0431	0.149	-0.115	-0.143	-37.05	0.129**	10.89	0.00759	-0.396***
	(0.117)	(0.342)	(0.126)	(0.114)	(27.12)	(0.0602)	(18.41)	(0.0566)	(0.145)
Gray/sandy soil	0.0413	0.261	0.194	-0.0737	2.933	0.0628	22.72	0.0372	-0.0313
	(0.123)	(0.360)	(0.132)	(0.121)	(30.16)	(0.0634)	(19.61)	(0.0596)	(0.155)
Distance to plot	-0.000582	0.00960	-0.000319	0.00129	0.965	-0.00424**	-0.434	-0.000416	-0.00556
	(0.00336)	(0.00983)	(0.00362)	(0.00329)	(0.905)	(0.00173)	(0.524)	(0.00163)	(0.00403)
Constant	0.570*	0.444	1.085***	0.672**	204.0**	0.794***	160.8***	0.0348	8.326***
	(0.294)	(0.861)	(0.317)	(0.288)	(80.90)	(0.152)	(45.65)	(0.143)	(0.355)
Observations	167	167	167	167	87	167	152	167	124
R-squared	0.377	0.649	0.423	0.403	0.453	0.495	0.699	0.200	0.626

Note: Distance is a dummy and equals to one if the control farmer is within the median minimum distance and zero otherwise. Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1